Final Project CS166

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The Simulation: Agricultural Trade

The model simulates agricultural trade. The possible firms are a choice of cow farm, grass farm, slaughterhouse, restaurant or fertilizer company. Outcome variables are total trade and total GDP.
This model provides a simplified version of international trade.

- 10 countries trade with each other with a total of 5 goods.
- Each country has a random choice of 3 out of 5 available firms.

Steps

At each iteration, a country first balances its local shortages and excesses by summing the production and consumption of each product at each firm. The total product count of each country is compared with each other country (in shuffled order at each iteration) and trades occur when applicable.[1] At each iteration the yearly trade volume is recorded. Excess or shortage of a product in a country in a year carries over to the next year. [2]

Measurements

The simulation measures total trade and total GDP after a certain amount of years.

Rules

Each firm can consume products (negative value) or produce products (positive value).

- cow farm: consumes grass, produces cows
- grass farm: consumes fertilizer, produces grass
- slaughter house: consumes cows, produces meat
- restaurant: consumes meat, produces money
- Fertilizer: consumes money, produces fertilizer

For simplicity, parameters are set to -10 and 10 respectively for each consumed and produced good.

Parameters

- **trade propensity:** If the economy is closed, the trade propensity for each country is sampled from a random normal distribution centered at 100, with a standard deviation of 20. If the economy is open, the normal distribution is centered at 10 with a standard deviation of 2. The propensity score is calculated by taking one over the absolute value of the random value. This results in the distribution not being purely normal anymore, is however a necessary measure in order to avoid “negative” trade.
- **cycle**: An economy can either be in a boom or a bust cycle. During a boom cycle and given a certain probability (pace), firms increase their baseline product usage by 1.2,

[1] This is a brute-force method and may not result in the optimal outcome. It compares the excess and shortage of all products of two countries and trades a percentage of the potential trade volume.
[2] This is an assumption made that would not hold in real life, as products such as meat are perishable.

indicating that all consumption and production of each country and firm increases by 20%. During a bust cycle, baseline usage decreases to 0.8, indicating a decrease of 20%.
- **pace:** The pace parameter indicates the probability at which the cycle specific increase or decrease occurs. The default is set to 0.5. A higher value leads to a faster increase or decrease of total output and thus trade volume. This parameter is bounded by 0 and 1.

The Model

A **Firm class** is the smallest instance in the network. The firms are designed to create a cycle in which each firm produces a good that another firm needs, and consumes a good another firm produced.

Parameters:
- **name**: the name of the firm (cow_farm, grass_farm, slaughter_house, restaurant, or fertilizer)
- **product_baseline**: a dictionary of the consumed and produced product (key) and quantity (value), each firm only consumes and produces one product
- **products**: a list of the two products that the firm either consumes or produces
- **cycle**: categorical variable of whether the firm is in a boom or bust cycle, this determines the volume of production and consumption based on product_baseline
- **pace**: the pace at which the cycle affects output
- **product_usage:** how much the firm consumes and produces, set to product_baseline

Methods:
- **calculate_usage():** product consumption and production after accounting for pace and cycle

A **Country class** is the middle instance in the network and contains a total of three firms that are randomly chosen.

Parameters:
- **name:** the name of the country as capitalized letter of the alphabet
- **firms:** an array of firm instances created in a helper function
- **products:** a list of products that the country consumes or produces across all firms
- **product_count**: a dictionary of each product and the count, initialized at 0
- **trade_propensity**: a float taken from a distribution defined outside the class, subject to whether the country is open or closed to trade
- **domestic_trade:** exchange of products/ services among firms within a country

Methods:

- **calculate_total()**: calculates the total usage of products across all firms to update the product count (sum of all consumption and production of all products across all firms)
- **return_tota()**: returns a list of all exchanges firms in a country want to engage in (=values of products of calculate_total())
- **calculate_domestic_GDP()**; calculates the domestic GDP by subtracting excesses/ shortages from total exchanges the firms of a country want to engage in

A **Network class** contains all countries with their respective firms, and conducts the trade.

Parameters:

- **countries**: a list of country instances
- **products:** a list of all products in the network of the given countries
- **total_trade:** a list (initiated empty) to count total trade at each step
- **total_GDP:** total GDP across all countries for each iteration
- **yearly_trade:** sum of total trade across all countries at each step

Methods:

- runs the first step of production and consumption by calling calculate_total() on each country when a network is initiated
- **step()**: iterates over each country combination to perform trade, adds the yearly trade to total_trade and shuffles countries to ensure a random order of trades at each iteration
- **trade(c1, c2)**: checks the excess and shortage of all overlapping products between two countries, and performs trade as demanded by shifting a share of the needed product from one country to the other (the share is determined by openness/ closedness of the country defined by its trade propensity)

Helper functions:

- **create_firms():** returns a list of firm instances for country class
- **create_countries():** returns a list of country instances for network class
- **single_simulation()**: runs the progression of an economy for (default) 10 years
- **total_simulation():** runs the simulation for monte carlo analysis

Assumptions

Products are float variables. In reality, most products have to be measured and traded as integer quantities. Trade volume is measured in units of trade, with each good being equally weighted. In reality, some products play a larger role in trade and exchange than others (e.g. cows as opposed to fertilizers).

Results and interpretation

Trade volume is positive for any economy in any cycle, but varies depending on context. GDP is negative as untraded products negatively contribute towards GDP, but can greatly be reduced via trade. The following simulations show trade volume after 10 years (iterations) at a normal pace (0.5) for the different cycle and economy statuses.

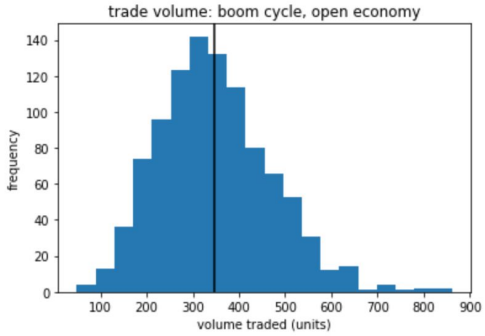
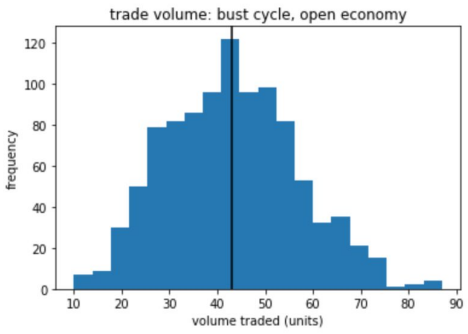
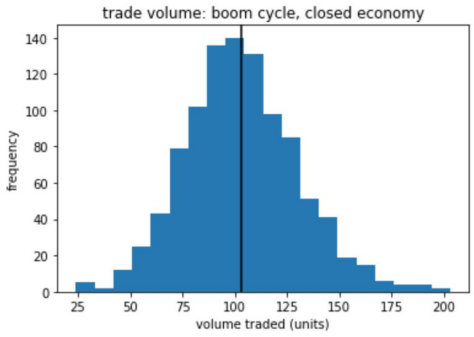
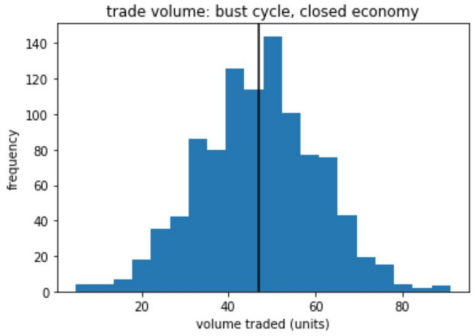
	cycle = boom	cycle = bust
economy = open	Mean: 347.348 Median: 336.5 95% confidence interval: [146.98, 608.10] 	Mean: 42.993 Median: 42.0 95% confidence interval: [19.00, 71.00] 
economy = closed	Mean: 103.309 Median: 102.0 95% confidence interval: [54.00, 160.07] 	Mean: 47.056 Median: 47.0 95% confidence interval: [21.00, 73.00] 

Table 1: Trade volume outcomes

	boom	bust
open	347	43
closed	103	47

Table 2: Trade volume overview

During a boom cycle, the trade volume outperforms boost by 347 to 43 units of trade in an open economy and by 103 to 47 units of a closed economy. As expected, for either open or closed economy a boom cycle shows higher trade volume than during the bust cycle. This indicates that during a boom period, it is relatively more beneficial to be an open than closed economy, generating eight times as much trade volume as opposed to twice as much.

An open economy outperforms a closed economy by 347 to 103 units during a boom cycle, but unexpectedly performs worse by 43 to 47 units during a bust. This indicates, that it is beneficial to be an open economy during a boom period, outperforming closed economies by more than three times as much trade. However, during a bust cycle, closed economies trade more than open economies. This may be due to higher exposure and vulnerability to economic changes, or randomness.

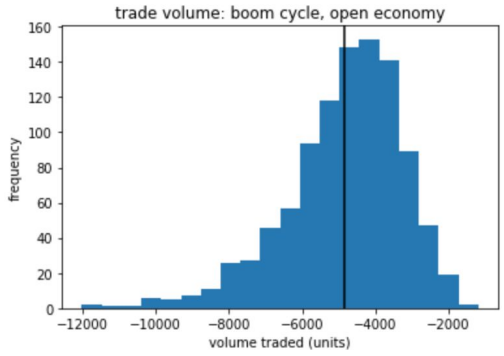
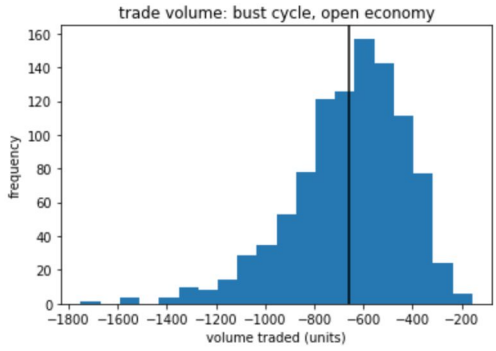
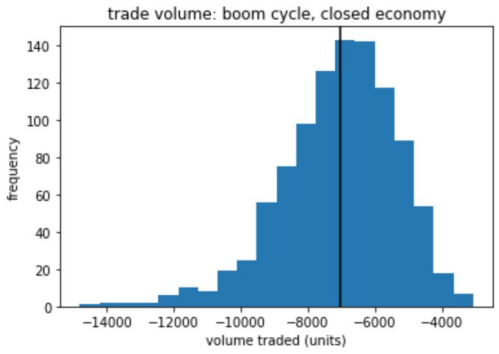
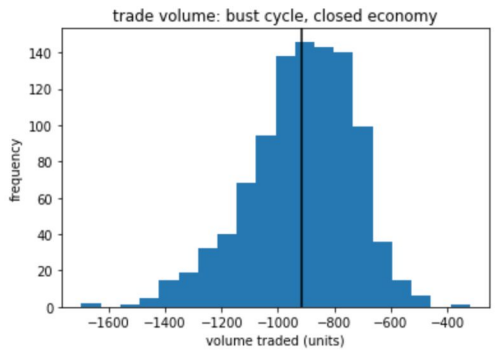
	cycle = boom	cycle = bust
economy = open	Mean: -4838.517009368384 Median: -4610.1576211549345 95% confidence interval: [-8364.95, -2374.87] 	Mean: -657.9285550418068 Median: -625.7745488114158 95% confidence interval: [-1217.44, -311.74] 
economy = closed	Mean: -7046.310391364789 Median: -6842.069486252685 95% confidence interval: [-11036.53, -4279.81] 	Mean: -915.142561298203 Median: -893.8513036606834 95% confidence interval: [-1345.60, -603.47] 

Table 3: GDP volume outcomes

	boom	bust
open	-4839	-658
closed	-7046	-915

Table 4: GDP volume overview

As expected, for both boom or bust periods closed economies perform worse than open economies, as their trade is restricted to within the borders (Table 4). This effect may be reduced by increasing the firm number within a country, as this gives the country the opportunity to balance out consumption demands and production supplies without having to engage in trade. This can be interpreted as a diversified economy, which many countries aim for to reduce reliance on other economies. More surprisingly, but understandably, GDP losses are larger during boom cycles than bust cycles, which is due to the overall increased volume of trade.

Distribution of outputs

With regards to trade, the distribution of outcomes is normal for closed economies, but slightly skewed to the right for open economies The results for GDP are much more skewed to the left for all outcomes, indicating that the mean is greater than the median, and larger losses are less likely to occur. (Table 3)

Uncertainty

95% confidence intervals (CI) were created for each simulation result. All confidence intervals had a medium to large width, such as for example the trade volume for open and boom, which showed a mean of 347 with lower bound of 14 and upper bound of 608. GDP estimates had wider lower estimates due to the skewness of the histogram, but similar upper estimates. For example the closed economy with a bust cycle had a mean of -915, with a lower bound of -1345 and upper bound of -603. These rather wide confidence intervals may be due to the small sample size of 1000 simulation runs.

To decrease this uncertainty, increasing the sample size narrows the confidence interval and thus provides more accurate point estimates. Generally, to reduce the confidence interval by half (divide by 2), the sample size has to be increased by four (multiply with 4), which multiplies the standard error by ½ and thus narrows the interval.

Policy Recommendation

Being an open economy is beneficial during a boom cycle, but harmful during bust. To decrease GDP losses during boom or bust cycles, being an open economy is advised.